Citation:

Mundt CA, Baxter-Jones AD, Whiting SJ, Bailey DA, Faulkner RA, Mirwald RL. Relationships of activity and sugar drink intake on fat mass development in youths. *Med Sci Sports Exerc.* 2006; 38(7): 1,245-1,254.

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Study Design:

Prospective Cohort Study

Class:

B - Click here for explanation of classification scheme.

Research Design and Implementation Rating:

POSITIVE: See Research Design and Implementation Criteria Checklist below.

Research Purpose:

To examine the relationship of physical activity and sugar-sweetened drink intake on the development of total body fat mass (FM). The author's hypothesized that when size, biological maturity age and their interactions are accounted for, both physical activity and sugar-sweetened drink intake should significantly predict fat accumulation.

Inclusion Criteria:

Participants were part of the University of Saskatchewan's Pediatric Bone Mineral Accrual Study (PBMAS).

Exclusion Criteria:

History of chronic disease or long-term medication use.

Description of Study Protocol:

Recruitment

Participants were part of the University of Saskatchewan's Pediatric Bone Mineral Accrual Study (PBMAS). In 1991, written informed consent was obtained from 228 parents and their children (113 boys and 115 girls).

Design

The study utilized a mixed longitudinal design and incorporated eight age cohorts. The cohorts were aged between eight and 15 years at baseline. During the seven years of annual data collection, the composition of these clusters remained the same.

Dietary Intake/Dietary Assessment Methodology

- Self-reported, 24-hour recall, administered three times per year in each of the first three years and then twice yearly each year thereafter. Yearly averages were then calculated and used for the analysis. A 20-minute training session on foodportion sizes was given to each participant prior to performing the initial data gathering. At each subsequent recall session, display boards with life-size pictures of food and portion sizes were present for participants' reference. Nutrient composition based on the 1988 Canadian nutrient file was used to analyze the 24-hour recalls
- Average total energy intake per day was calculated ($kcal \cdot d^{-1}$). As intakes varied considerably due to activity and body size, as well as errors in reporting intakes, calories ($kcal \cdot d^{-1}$) from sugar-sweetened drink intake were removed from the total energy intake value. The purpose of this adjustment was to isolate the influence of sugar-sweetened drink intake in the analysis and also control for participant's energy consumption apart from sweetened drinks
- Consumption of sugar-sweetened beverages was assessed at each measurement occasion. Of interest were beverages that contained added sugar such as soft drinks, sport drinks, drinks made from crystals or flavored syrup, punches less than 50% real juice, milkshakes, liquid yogurt, hot chocolate and iced tea. Focus was on sugar-sweetened drinks outside of 100% fruit juice because such drinks are regarded as a source of "emptycalories," lacking significant amounts of other beneficial nutrients. Sugar-sweetened drinks were assumed to contain 12 $kcal \cdot oz^{-1}$. Using this value, the energy contained in the sugar-sweetened drink total was estimated and subtracted from the recorded total energy intake.

Statistical Analysis

- Descriptive results are expressed as mean ± SEM (SPSS version 11.5, SPSS Inc., Chicago, IL). Age group comparisons were made with T-tests ($P<0.05$) and Bonferroni adjustments were made for multiple comparisons. The hypotheses were tested using hierarchical (multilevel) linear modeling using random effects models (MlwiN version 1.0, Multilevel Models Project, Institute of Education, University of London, London, UK)
- Additive and gender-specific multilevel regression models were developed to describe the developmental changes in FM (kg) as follows: Where y is the FM on the measurement occasion i in the jth individual, $[alpha]_j$ is the constant for the jth individual, $[beta]_j x_{ij}$ is the slope of fat mass with biological age (years from PHV) for the jth individual, and k_1 to k_n are the coefficients of various explanatory variables [e.g., physical activity (PAQ score one to five), sugar-sweetened drink ($oz \cdot d^{-1}$), adjusted total energy expenditure ($kcal \cdot d^{-1}$)] at assessment occasion i in the jth individual, and $[epsilon]_{ij}$ is the level one residual (within individual variance) for the ith assessment of FM in the jth individual
- Modeling strategy: Models were built in a stepwise procedure; that is, predictor variables ([kappa]-fixed effects) were added one at a time.

Likelihood ratio statistics were used to determine whether the effects of independent variables were significant contributors to the model. The difference in likelihood between two models follows a chi-square distribution; this difference was compared against the degrees of freedom lost to determine whether one model was a significant improvement over the other. In this way, predictor variables were added to the models and retained if deviance improved or if the variances at levels one and two were reduced. Predictor variables ([kappa]) were accepted as significant if the estimated mean coefficient was greater than twice the SEE (P<0.05). If the retention criteria were not met, the predictor variable was discarded. Biological age was added as both a fixed and random coefficient. To allow for the non-linearity of growth, age power functions (biological age^2 and biological age^3) were added to the models as fixed effects. Once age, FFM and total energy intake were modeled, physical activity and sugar-sweetened drink consumption and their interaction were incorporated into the models and their independent effects were

Data Collection Summary:

Timing of Measurements

1991 to 1997.

Dependent Variables

- Fat mass and relative percent fat mass: DXA
- Physical activity: Physical activity questionnaire for children (PAQ-C) and adolescents (PAQ-A); the instrument scores nine items on a five-point scale, with a higher value indicating higher levels of physical activity
- Sugar-sweetened drink (ounces per day): Dietary recall.

Independent Variables

- Age at peak heat velocity, calculated from velocity stature growth
- Gender.

Control Variables

Biological maturity age index.

Description of Actual Data Sample:

- *Initial N:* 113 males, 115 females
- *Attrition (final N):* 105 males, 103 females
- *Age:* Eight to 19 years old
- *Ethnicity:* Australian
- *Other relevant demographics:* Males were older (P<0.05), taller (P<0.05) and heavier (P<0.05) than females when compared across biological maturity categories
- *Anthropometrics:* No significant (NS) gender difference (P>0.05) in absolute fat mass was observed until after PHV had been attained
- *Location:* Australia.

Summary of Results:

- NS gender differences in total energy intake or biological maturity category for physical activity were found prior to PHV
- Post-PHV, total energy intake significantly decreased in females and increased in males
- Sugar-sweetened drink consumption appears to increase with increasing biological maturity; however, significant (P<0.05) gender differences were only found at two and three years post-PHV
- For all four gender specific models, the significant variances at level one of the models indicate that FM was increasing significantly at each measurement occasion within individuals (E more than 2*SEE; P<0.05)
- The between-individuals variance matrix (level two) for each model indicates that individuals had significantly different FM curves both in terms of their intercepts (constant/constant, P<0.05) and the slopes of their lines (biological age/biological age, P<0.05)
- Once biological age (years from PHV) and FFM effects were controlled, there was no significant independent physical activity effect in females (Table 2, PA model), but in males, there was a significant physical activity effect (P<0.05) (Table 3, PA model)
- Once biological age, FFM and total energy intake were controlled, there was NS effect of sugar-sweetened drink consumption in either females or males (Tables 2 and 3, SD models).

Table 2. Multi-level Regression Analysis of Fat Mass Development (kg) of Females

Variables	Base Model Estimates		PA Model Estimates		SA Model Estimates		Interaction Estimates	
Fixed effects constant	2.96±1.92		3.29±1.98		3.32±1.98		3.69± 2.04	
BA	1.02±0.226		0.987±0.226		1.06±0.227		1.05±0.229	
BA^2	0.065±0.0231		0.0634±0.0232		0.0688±0.0232		0.0635±0.0233	
BA^3	-0.00226±0.00447		-0.00211±0.00047		-0.00321±0.00450		-0.00248±0.00452	
FFM	0.313±0.0580		0.318±0.0582		0.298±0.0585		0.305±0.0586	
PA	N/A		-0.166±0.230		N/A		-0.152±0.229	
ATEI	N/A		N/A		0.000160±0.000210		0.000150±0.000210	

SD	N/A		N/A		-0.0188±0.0118		-0.0169±0.0119	
PA*SD	N/A		N/A		N/A		-0.00642±0.00430	
Random effects constant	Level 1: 2.96±0.229		Level 1: 2.97±0.229		Level 1: 2.93±0.227		Level 1: 2.92±0.226	
	Level 2		**Level 2**		**Level 2**		**Level 2**	
	Constant	**BA**	**Constant**	**BA**	**Constant**	**BA**	**Constant**	**BA**
Constant	34.0±4.82	3.09± 0.620	33.7±4.77	3.07±0.615	34.2±4.81	3.10±0.621	33.6±4.75	3.11±0.619
BA	3.09±0.620	0.690± 0.130	3.07±0.615	0.683±0.129	3.10±0.621	0.695±0.130	3.11±0.619	0.702±0.131

Fixed effect values are estimated mean coefficients ± SEE (fat mass, kg).

Random effect values estimated mean variance ±SEE (fat mass, kg^2).

BA, biological age, years from age at peak height velocity; FFM, fat-free mass (kg); PA, physical activity score (one low, five high); ATEI, adjusted total energy intake, adjusted for sugar-sweetened drink intake (kcal per day); SD, sugar-sweetened drink (oz per day).

P<0.05 if estimated mean more than 2* SEE.

Table 3. Multilevel Regression Analysis of Fat Mass Development (kg) of Males

Variables	Base Model Estimates		PA Model Estimates		SA Model Estimates		Interaction Estimates	
Fixed effects constant	20.1±2.02		21.6±2.13		19.7±2.04		21.2±2.15	
BA	1.84±0.300		1.72±0.306		1.81±0.300		1.70 ±0.306	
BA^2	-0.0250±0.0197		-0.0374±0.0207		-0.0231±0.0196		-0.0353±0.0206	
BA^3	0.000910±0.00642		0.00251±0.00646		-0.00160±0.00643		0.00317±0.00646	
FFM	-0.228±0.0453		-0.233±0.0452		-0.219±0.0455		-0.216±0.0455	
PA	N/A		-0.547±0.268*		N/A		-0.539*±0.268	
ATEI	N/A		N/A		0.0000600±0.000130		0.0000600±0.000130	
SD	N/A		N/A		-0.0141±0.00846		-0.0138±0.00843	
PA*SD	N/A		N/A		N/A		0.00152±0.00283	
Random effects constant	Level 1: 3.27±0.254		Level 1: 3.21±0.249		Level 1: 3.25±0.252		Level 1: 3.19±0.248	
	Level 2		**Level 2**		**Level 2**		**Level 2**	
	Constant	**BA**	**Constant**	**BA**	**Constant**	**BA**	**Constant**	**BA**
Constant	47.1±6.70	3.95±0.828	47.2±6.72	4.00± 0.837	46.9±6.68	3.95±0.824	33.6±6.71	4.02± +/- 0.836
BA	3.95±0.828	0.827±0.157	4.00±0.837	0.853± 0.160	3.95±0.824	0.824±0.156	4.02±0.836	0.851± +/- 0.159

Fixed effect values are estimated mean coefficients ± SEE (fat mass, kg).

Random effect values estimated mean variance ± SEE (fat mass, kg^2).

BA, biological age, years from age at peak height velocity; FFM, fat-free mass (kg); PA, physical activity score (one low, five high); ATEI, adjusted total energy intake, adjusted for sugar-sweetened drink intake (kcal per day); SD, sugar-sweetened drink (oz per day).

P<0.05 if estimated mean more than 2* SEE.

Author Conclusion:

- Physical activity had a significant negative relationship on FM development in males, but not females
- Sugar-sweetened drink intake was NS related to FM development in either males or females
- There were no interactions found between physical activity and sweetened drink consumption in either gender.

Reviewer Comments:

The author's noted the following limitations:

- *DXA has been determined to be a valid and reliable instrument for body composition assessment; however, its ability to assess body composition in children and adolescents has been questioned. DXA employs assumptions that mineral and water content of the fat-free body are constant, but such assumptions may not hold true in growing individuals*
- *The PAQ-C/A questionnaire used to assess physical activity has demonstrated good internal consistency and validity with several other evaluations of activity level; however, it is a self-reported assessment and therefore has the associated limitations*
- *The food recall procedure is thought to offer the best method of obtaining a dietary record although it is also a self-reported measure and has associated limitations*
- *Self-reported measures are susceptible to under-reporting, especially among those who are overweight or obese*
- *The limited frequency of dietary assessment might have served to exaggerate the weaknesses of the 24-hour recall if under-reporting occurred on many or all occasions. It also may, in part, account for the low reported energy intake while growth was still occurring.*

Research Design and Implementation Criteria Checklist: Primary Research

Relevance Questions		
1.	Would implementing the studied intervention or procedure (if found successful) result in improved outcomes for the patients/clients/population group? (Not Applicable for some epidemiological studies)	N/A
2.	Did the authors study an outcome (dependent variable) or topic that the patients/clients/population group would care about?	Yes
3.	Is the focus of the intervention or procedure (independent variable) or topic of study a common issue of concern to nutrition or dietetics practice?	Yes
4.	Is the intervention or procedure feasible? (NA for some epidemiological studies)	N/A

Validity Questions		
1.	**Was the research question clearly stated?**	Yes
1.1.	Was (were) the specific intervention(s) or procedure(s) [independent variable(s)] identified?	Yes
1.2.	Was (were) the outcome(s) [dependent variable(s)] clearly indicated?	Yes
1.3.	Were the target population and setting specified?	Yes
2.	**Was the selection of study subjects/patients free from bias?**	Yes
2.1.	Were inclusion/exclusion criteria specified (e.g., risk, point in disease progression, diagnostic or prognosis criteria), and with sufficient detail and without omitting criteria critical to the study?	Yes
2.2.	Were criteria applied equally to all study groups?	Yes
2.3.	Were health, demographics, and other characteristics of subjects described?	Yes
2.4.	Were the subjects/patients a representative sample of the relevant population?	No
3.	**Were study groups comparable?**	Yes
3.1.	Was the method of assigning subjects/patients to groups described and unbiased? (Method of randomization identified if RCT)	N/A
3.2.	Were distribution of disease status, prognostic factors, and other factors (e.g., demographics) similar across study groups at baseline?	N/A
3.3.	Were concurrent controls used? (Concurrent preferred over historical controls.)	N/A
3.4.	If cohort study or cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis?	Yes
3.5.	If case control or cross-sectional study, were potential confounding factors comparable for cases and controls? (If case series or trial with subjects serving as own control, this criterion is not applicable. Criterion may not be applicable in some cross-sectional studies.)	N/A
3.6.	If diagnostic test, was there an independent blind comparison with an appropriate reference standard (e.g., "gold standard")?	N/A
4.	**Was method of handling withdrawals described?**	Yes
4.1.	Were follow-up methods described and the same for all groups?	Yes

4.2.	Was the number, characteristics of withdrawals (i.e., dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for each group? (Follow up goal for a strong study is 80%.)	Yes
4.3.	Were all enrolled subjects/patients (in the original sample) accounted for?	Yes
4.4.	Were reasons for withdrawals similar across groups?	N/A
4.5.	If diagnostic test, was decision to perform reference test not dependent on results of test under study?	N/A
5.	**Was blinding used to prevent introduction of bias?**	Yes
5.1.	In intervention study, were subjects, clinicians/practitioners, and investigators blinded to treatment group, as appropriate?	N/A
5.2.	Were data collectors blinded for outcomes assessment? (If outcome is measured using an objective test, such as a lab value, this criterion is assumed to be met.)	N/A
5.3.	In cohort study or cross-sectional study, were measurements of outcomes and risk factors blinded?	Yes
5.4.	In case control study, was case definition explicit and case ascertainment not influenced by exposure status?	N/A
5.5.	In diagnostic study, were test results blinded to patient history and other test results?	N/A
6.	**Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were interveningfactors described?**	Yes
6.1.	In RCT or other intervention trial, were protocols described for all regimens studied?	N/A
6.2.	In observational study, were interventions, study settings, and clinicians/provider described?	No
6.3.	Was the intensity and duration of the intervention or exposure factor sufficient to produce a meaningful effect?	Yes
6.4.	Was the amount of exposure and, if relevant, subject/patient compliance measured?	Yes
6.5.	Were co-interventions (e.g., ancillary treatments, other therapies) described?	Yes
6.6.	Were extra or unplanned treatments described?	Yes
6.7.	Was the information for 6.4, 6.5, and 6.6 assessed the same way for all groups?	Yes
6.8.	In diagnostic study, were details of test administration and replication sufficient?	N/A
7.	**Were outcomes clearly defined and the measurements valid and reliable?**	Yes
7.1.	Were primary and secondary endpoints described and relevant to the question?	Yes
7.2.	Were nutrition measures appropriate to question and outcomes of concern?	Yes
7.3.	Was the period of follow-up long enough for important outcome(s) to occur?	Yes
7.4.	Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?	Yes
7.5.	Was the measurement of effect at an appropriate level of precision?	Yes
7.6.	Were other factors accounted for (measured) that could affect outcomes?	Yes
7.7.	Were the measurements conducted consistently across groups?	Yes
8.	**Was the statistical analysis appropriate for the study design and type of outcome indicators?**	Yes
8.1.	Were statistical analyses adequately described and the results reported appropriately?	Yes
8.2.	Were correct statistical tests used and assumptions of test not violated?	Yes
8.3.	Were statistics reported with levels of significance and/or confidence intervals?	Yes
8.4.	Was "intent to treat" analysis of outcomes done (and as appropriate, was there an analysis of outcomes for those maximally exposed or a dose-response analysis)?	N/A
8.5.	Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?	Yes

	8.6.	Was clinical significance as well as statistical significance reported?	Yes
	8.7.	If negative findings, was a power calculation reported to address type 2 error?	N/A
9.	**Are conclusions supported by results with biases and limitations taken into consideration?**		Yes
	9.1.	Is there a discussion of findings?	Yes
	9.2.	Are biases and study limitations identified and discussed?	Yes
10.	**Is bias due to study's funding or sponsorship unlikely?**		Yes
	10.1.	Were sources of funding and investigators' affiliations described?	Yes
	10.2.	Was the study free from apparent conflict of interest?	Yes